

Research on the Changes of Cement Production Method in China

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Abstract. Cement production plays an important role in affecting total amount of greenhouse gases emission. In recent years, China's cement production begins to maintain below an exact point instead of following the continuous growing trend that experts anticipate. Until today, most people are still unaware of transition of China's cement production method. Therefore, this paper focuses on investigating changes of cement production method in China. The method of investigating these changes is analyzing previous cement production situation of China, then listing three cement production method which two of them are traditional methods and another one New Suspension Preheater (NSP) rotary kiln production is new method and comparing environmental effect caused by three methods respectively, and finally analyzing benefits of new production method and other action the government take to mitigate greenhouse effect and showing their effects. Research result shows that NSP rotary kiln production has advantages over traditional production methods and almost all the factories in China are using this production method.

Keywords: NSP rotary kiln cement production; Carbon dioxide emission; Global warming potential; PM 2.5.

1. Introduction

Nowadays, with the development of new technology, industrial production is becoming more efficient and qualitative. Many products produced by factories can influence people's daily life. From the normal transportation to construction materials used to build modern skyscraper, industrial production undoubtedly makes people's life more convenient. However, the massive industrial emission also causes people to concern about consequence brought by unrestrained production, which can increase the level of particulate matter (PM) 2.5 and accelerate the greenhouse effect. Take a closer look in cement production industry. Being one of the world's most energy-consuming industries, it contributes 7% of global industrial energy use and 27% of global industrial carbon dioxide emissions. Meanwhile, among the total emission of greenhouse gases, China takes up almost half of it.

As playing an important role in the development of China and rapid growth rate of urbanization, the cement industry was responsible for 6.8%, 2.6%, and 14.4% of the national total PM, sulfur dioxide (SO₂), and nitrogen oxides (NOX) emissions in 2015, with the latter two contributing more than double those figures. It is estimated that the growth of Chinese cement industry will continue growing in the future, which can cause more severe environmental problems. However, in recent years, Chinese cement production has begun to stay below an exact value and keep a proportion of about 50% of world cement production. Moreover, policies have been made in order to restrict emission of gas in some provinces. All these results about actions carried out by Chinese government and businesses has led to heated debate and hypothesis. Therefore, investigating the change in cement production in China can solve others' questions and is meaningful to global environmental protection.

This paper focuses on investigating different methods of cement production in different periods. Moreover, the process includes evaluating previous and modern cement production methods, calculating its Global Warming Potential (GWP) and comparing their influence to the environment. By analyzing different cement production methods, there is a summary for advantages and disadvantages of these production methods, and examination about real environmental effect on from cement industry is given out by adding reference about government policies in different provinces.



2. Cement Production

2.1. Features of Cement in Production

Cement is a fine gray powdery substance that is mixed with water and other materials to create mortar, or it can be mixed with sand, gravel, and water to produce concrete [1]. It has several properties that play important role in residential and commercial construction work and global environment:

(1) High compressive strength

Before cement hydrates, there are lots of pores filled with water inside it, which take up most of its space. By contrast, after continuous hydration, these pores shrink and are filled with solid hydrate products. The process of reducing porosity finally contribute to the property of high compressive strength. Because of this feature, cement is usually used to support heavy loads in structures like buildings, bridges and dam.

(2) Ability to bind with other materials

Cement is always mixed with sand and gravel to form concrete, and because the mix of cement can not only fix extra small pores in cement but can also strength the whole product, the final product can set a steady base for the construction.

(3) High carbon dioxide emissions during production

Limestone is the primary raw material used to make cement. It is heated in a kiln at high temperature and then produces calcium oxide and carbon dioxide through a chemical reaction, resulting in large amounts of carbon dioxide emission and continuous global warming which can be seen in Fig. 1 about global cement and fossil energy production from 1900 to 2018. Moreover, cement itself contains much carbon and can lead to consistent emission in the following years.

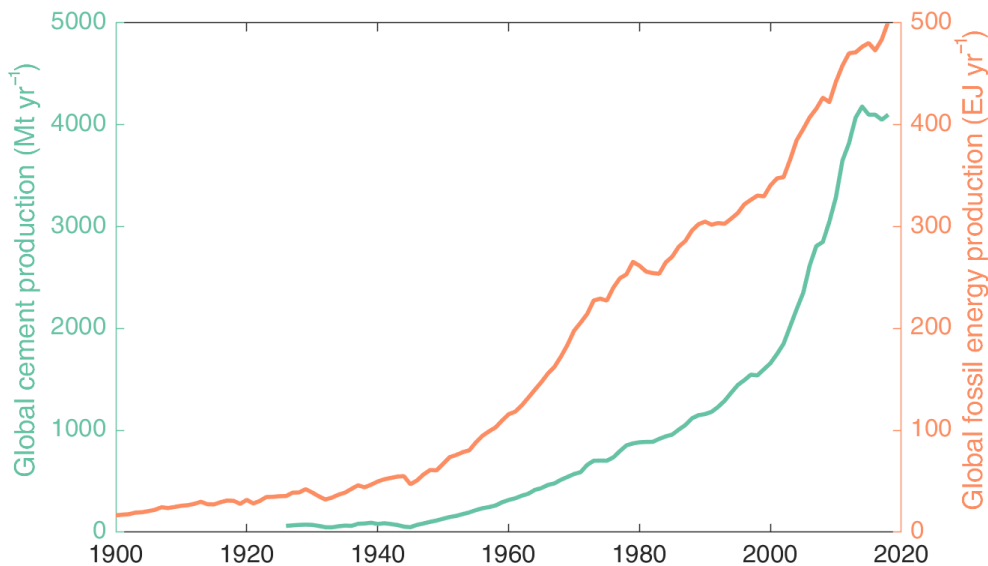


Figure 1. Carbon dioxide emission graph [2]

2.2. Cement Production in China

The trend that China's cement production has steadily increased since 1978, which was the beginning of After the reform and opening, can be obviously seen in Fig. 2.

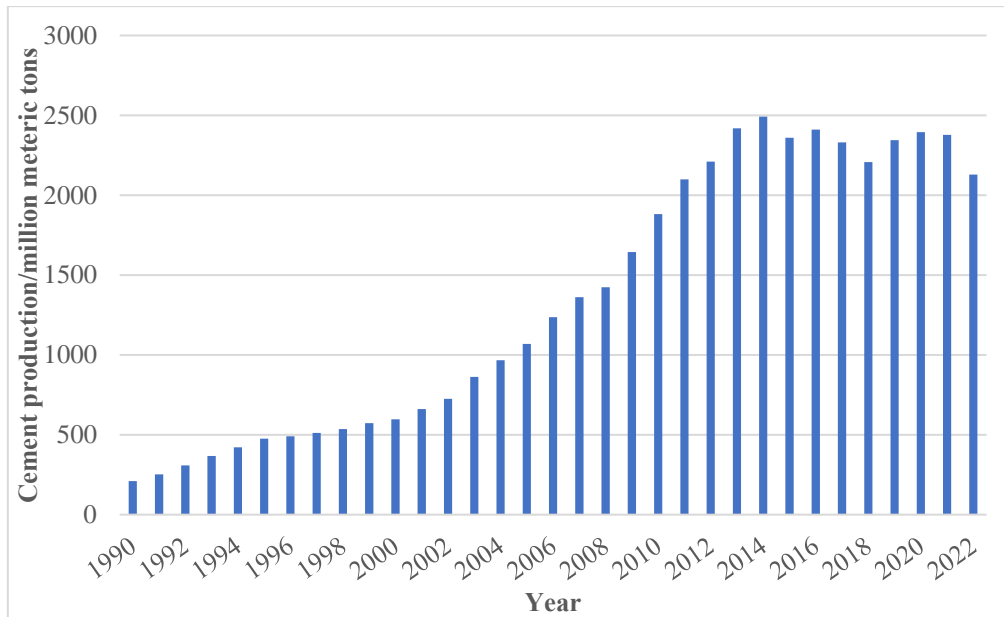


Figure 2. Cement production pattern of China

In Fig. 2, the cement production reached the peak point in 2014, which is 2492.07 million metric tons. While then it began to reduce and maintain a proportion about 50% of the global cement production because of the rising awareness of environmentally cement production. Before 2014, China is responsible for 60% of the world's cement production, and its production from 2011 to 2013 was higher than the United States' production for the entire 20th century [3]. The negative impact of using shaft kilns and rotary kilns in the past can be obviously shown in Fig. 2.

Because of large emission of carbon dioxide from cement and other industrial production before, concentrations of particles like PM 2.5 which can affect air quality increased before 2014, causing the government to concern the environmental impact brought by massive production and to start editing policy about cement production. Fig. 3 shows deaths caused by air pollution can better show the effect of massive cement production [4].

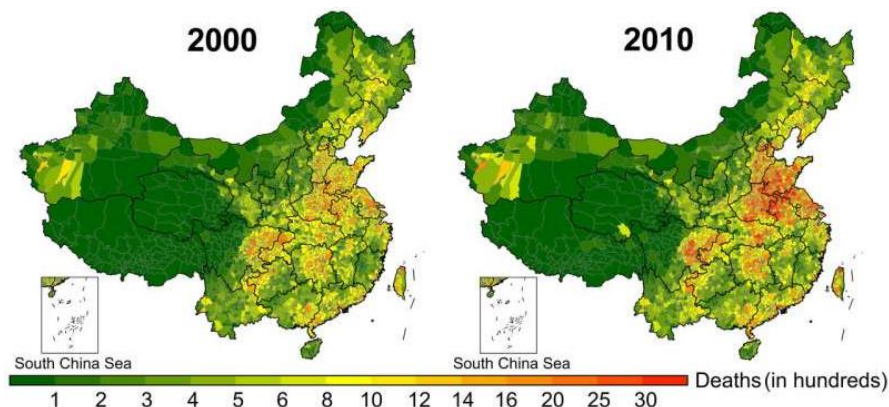


Figure 3. Deaths caused by air pollution [4]

2.3. Cement Production in Hebei Province

Hebei Province is a major source of industrial pollutants in China because it plays an important role in producing industrial materials. Moreover, Hebei is located in Beijing-Tianjin-Hebei region, which is an area that need massive industrial production in order to feed large amounts of people. As shown in Fig. 4, in 2013, cement production in Hebei Province reached 127.7 Million tons, about 5.3% of total national cement production. The massive production of cement and other construction material caused the air quality of Hebei Province decrease continuously and increase concentration of PM2.5 in the atmosphere. In 2013, the total emitted carbon dioxide in Beijing-Tianjin-Hebei area is 963.9

Million tons, which take up 10.3% of the total national emission. Among the region, the highest carbon dioxide emission can be found in Hebei province, which is 734.9 Million tons and accounts for 8.0% of the total national emission [5].

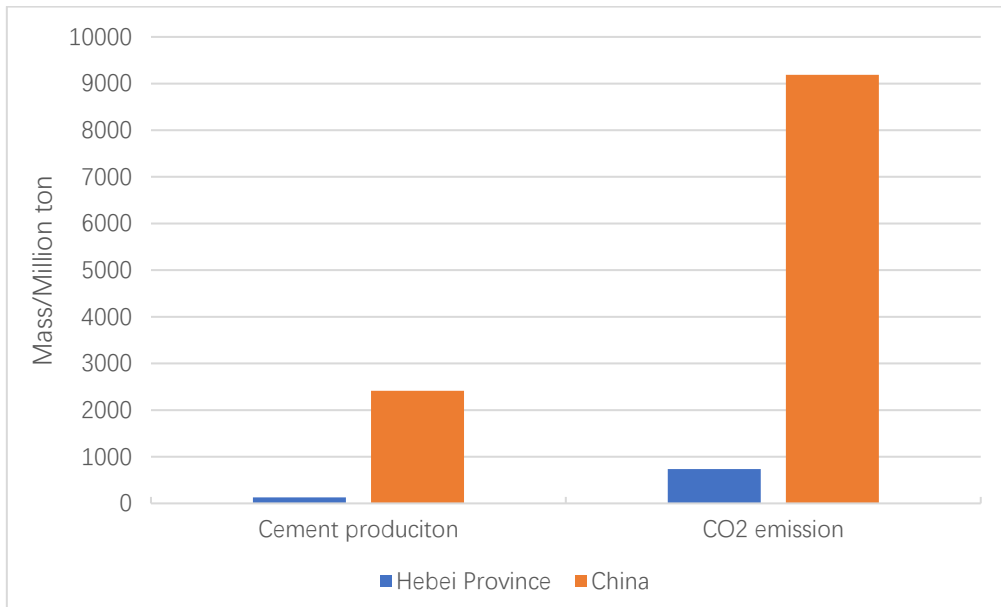


Figure 4. Cement production and CO₂ emission in Hebei and China (Data form [5])

3. Three Main Cement Production Methods

There are many ways for industry to produce cement, and three of them are used most frequently: shaft kiln production, rotary kiln production, and NSP rotary kiln production (a new production method that is not included in rotary kiln production part).

3.1. Shaft Kiln Production

Shaft kiln is a type of vertical and fixed clinker firing equipment that is also referred to as vertical shaft kiln, which is shown in Fig. 5 [6].

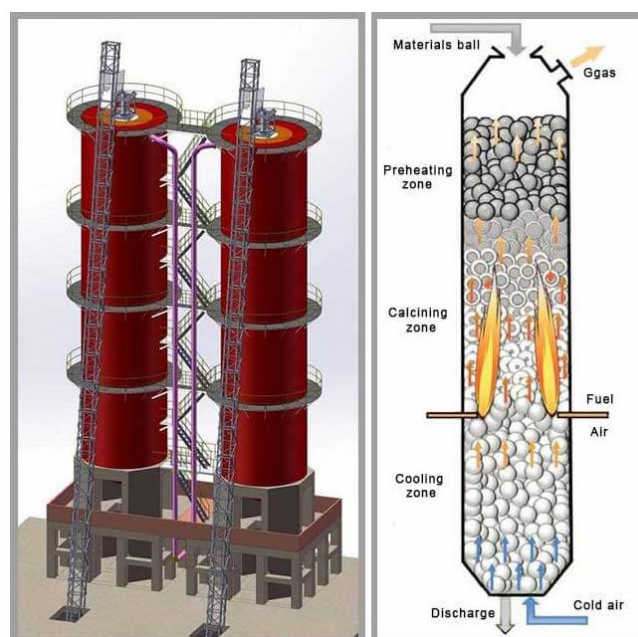


Figure 5. Internal structure of shaft kiln [6]

Companies always use equipment to process small or medium-sized cement plant for producing clinker manufacturing [7]. There are three main processes for the production: preheating zone, calcining zone and cooling zone. Firstly, raw materials with coal are dropped into the cement kiln from the kiln crown above, and the air is moving from bottom to the top at the same time. Affected by gravity, the raw material descends to the bottom of shaft kiln continuously and its temperature starts increasing consistently. Then when the ball falls into the calcining zone, its temperature continues rising to over 1200°C, causing other materials to turn into liquid phase and enabling limes to react with silica and other materials to form clinker. In the cooling zone, the new produced clinker exchanges heat with cold air from the bottom and becomes cooled. After cooling, the clinker is ground with gypsum to produce cement. This method can be seen as the ordinary shaft kiln to produce cement. However, it produces a large amount of gas like carbon dioxide, nitrogen dioxide and formaldehyde and make the global warming condition more severe.

3.2. Rotary Kiln Production

The rotary kiln is composed of a cylinder that is positioned slightly to the left and rotates around its axis, which weighs kilograms, has a length of a hectometer, and four to nine supports, which can all be seen in the Fig. 6 [8].

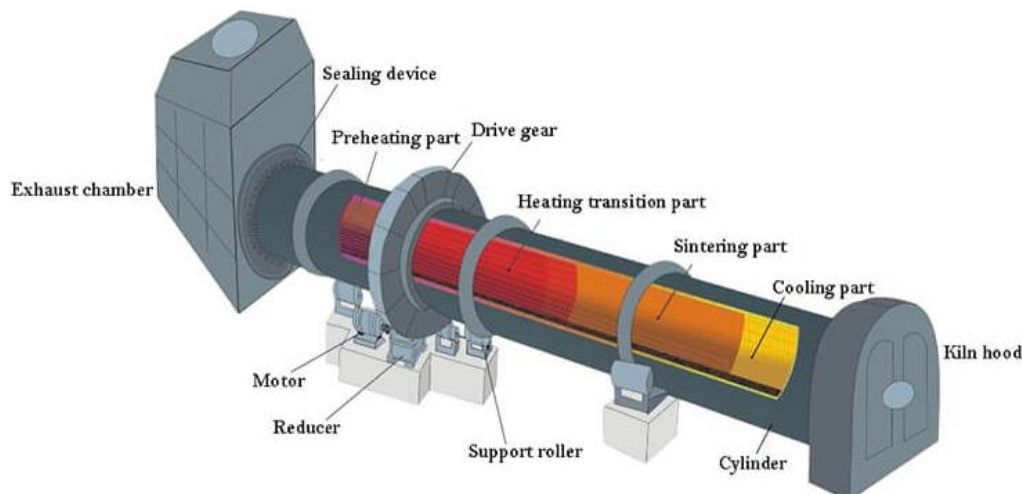


Figure 6. Rotary kiln diagram [8]

Calcium oxide is the basis for cement clinker particles during processing when limestone is decomposed in this equipment [7]. The heat is supplied by the equipment to elevate the solids inside to reaction temperatures and encourage efficient mixing. Although there are some advantages on using rotary kilns cement production, for example, higher efficiency compared to shaft kiln production, published estimates suggest that the cement industry generated around 5-10% of all man-made greenhouse emissions. As a result, the cement sector is one of the largest contributors to greenhouse gases in the industrial sector; thus, the mass emission of these gases can also cause more rapid growth of global warming.

3.3. NSP Rotary Kiln Production

NSP rotary kiln production is a modern kind of cement kiln for cement manufacturing. It has preheating, calcination, clinker formation, clinker cooling and clinker grinding steps, which seems like shaft kilns and rotary kilns. However, raw mix is heated before entering the kiln and the cooling process allows heat to recirculate back to the rotary kiln. These two changes help NSP rotary kiln to achieve same cement production in lower energy consumption, lower carbon dioxide emission and higher working efficiency.

3.4. Benefit of NSP Rotary Kiln Production

With the development of new technique for cement production, traditional cement productions like shaft kiln and rotary kiln are less used by governments and companies, while new methods like NSP rotary kiln are gradually accepted by more people. This paper focuses on the environmental benefits of NSP rotary kiln production. Using the greenhouse gas emissions of a component or technology's life cycle, from production to disposal, the GWP is used to assess the potential climate impact of a component or technology. Therefore, the cement production method with higher GWP value will emit more greenhouse gases to the atmosphere. By calculating the GWP value of shaft kilns, rotary kilns (not includes NSP rotary kilns) and NSP, people can know their which one of them is the most environmental-friendly. According to the equation of global warming, which is:

$$Global\ Warming = \sum_i GWP_i \times m_i \quad (1)$$

The value of GWP about carbon dioxide, nitrogen dioxide and formaldehyde are 1, 265 and 28 respectively [9]. Meanwhile, mass of these gases emitted from different cement production methods are list in Table 1.

Table 1. Mass of different gases produced in three production methods

Production methods	CO ₂ /kg	N ₂ O/kg	CH ₄ /kg
Shaft kilns	847.85	0.2	0.035
Rotary kilns	900	0.15	0.02
NSP rotary kilns	520	0.05	0.005

Therefore, their impact on the environment can be calculated by using the equation of GWP, as shown in Table 2.

Table 2. GWP value of three cement production methods

GWP/kgCO ₂ eq	CO ₂	N ₂ O	CH ₄	Sum
Shaft kilns	847.85	53	0.88375	901.73375
Rotary kilns	900	39.75	0.505	940.255
NSP rotary kilns	520	13.25	0.12625	533.37625

According to Table 2, the impact of GWP when using NSP rotary kilns is much less than shaft kilns and rotary kilns, and obviously, gases like N₂O which has higher GWP value are obviously reduced. Moreover, their differences can be seen more obviously on Fig. 7.

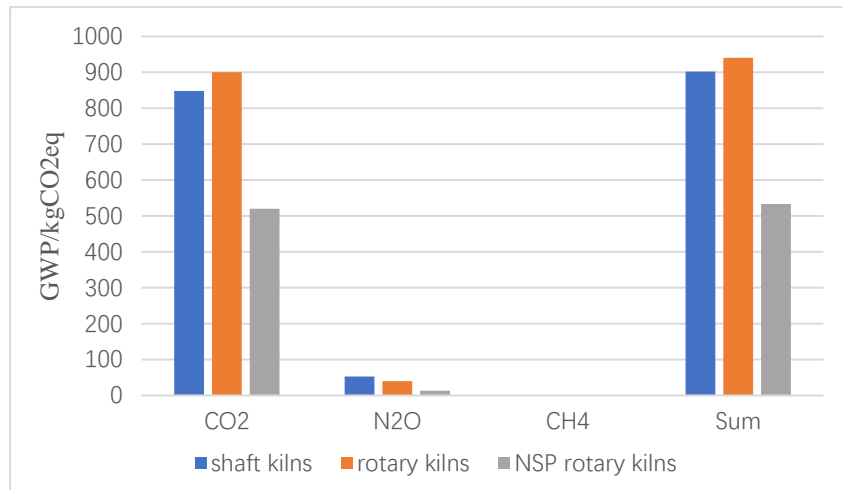


Figure 7. GWP of three cement production methods

In addition to the advantage of having a smaller impact on the environment, NSP rotary kilns production also has higher working efficiency and lower energy consumption. Compared to other traditional cement production, the innovative preheating zone and cooling zones allow factories to preheat the lime before entering into the kiln. Therefore, the calculation of GWP values and other factors show that NSP rotary kiln cement production is more friendly to both factories and the environment.

4. Transformation of Cement Production Method

4.1. Changes of Cement Production Method

In order to mitigate the air pollution and accelerating global-warming effect, the government and factories begin to take some actions.

(1) Encouraging and promoting the use of NSP rotary kilns production

According to the calculation of GWP values above, the impact of the NSP rotary kiln is much lower than the other two methods in the areas of climate change, fossil depletion, and PM formation, which can reduce concentration of PM_{2.5} in the air and decelerate global warming effect. Since 21st century, Chinese government began to introduce NSP rotary kiln cement production to different provinces and the changes of production method can be obviously seen in Fig. 8. In Fig. 8(a) and (b), it is clear to see that the proportional of NSP rotary kilns increased from less than 20% to nearly 100% and mass of cement production also increased but has begun to stay below an exact point since 2014. In Fig. 8(c) and (d), there are less than 25% of factories in Hebei Province that used NSP rotary kiln to produce cement in 2001 while this number increased to nearly 95% in 2014. Moreover, Sichuan Province is an inland province in China and also plays an important role in cement production. In 2021, there are only about 5% of industries that used NSP rotary kiln while this number increased to over 80% in 2014 [10].

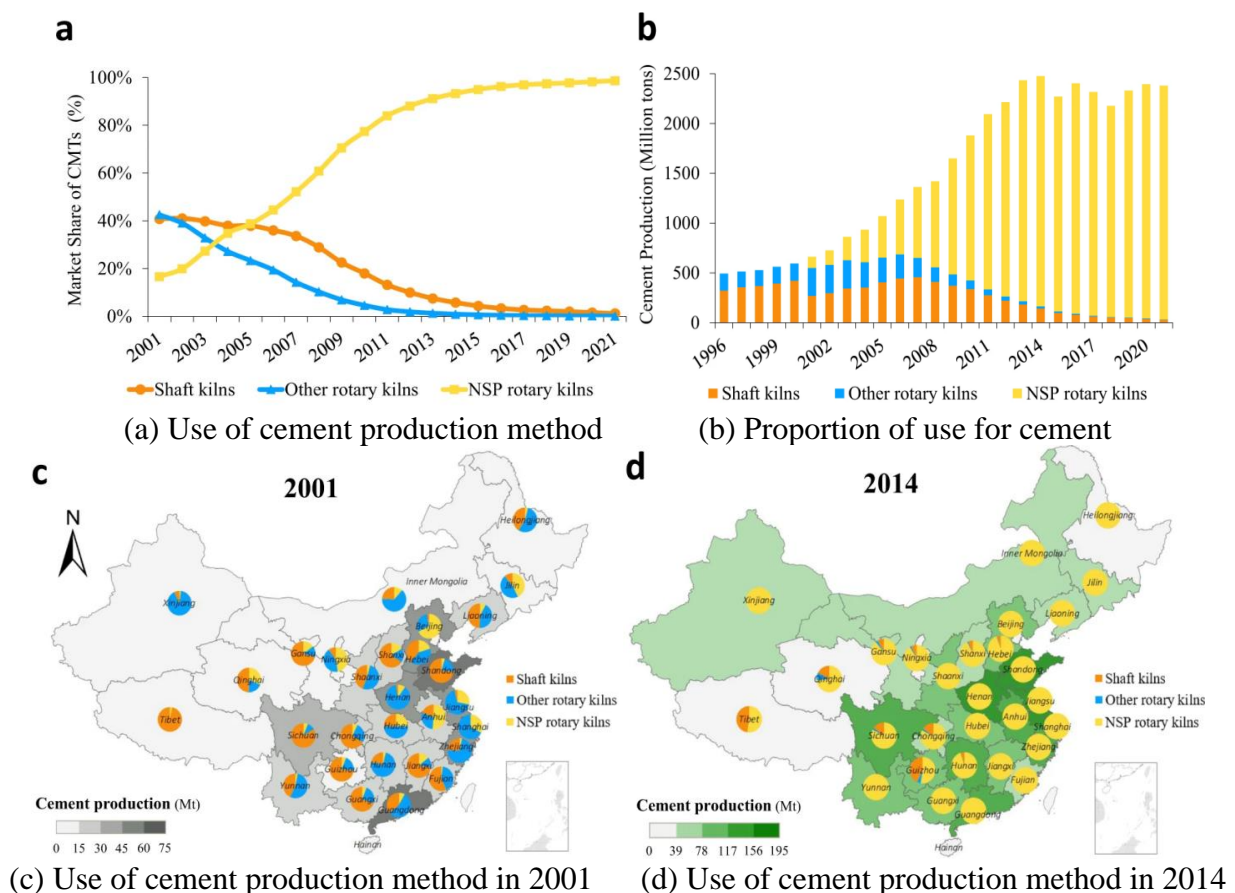


Figure 8. The changes of production method [10]

(2) Planing off-peak gas emission and restrain quantity of emitted gas

Many provinces like Sichuan plans off-peak gas emission in order to restrict massive gas emission at a fixed time and in other days, kilns for producing cement need to be closed. Meanwhile, the quantity of emitted gas should be determined by factors like environmental protection, energy consumption, and environmentally sensitive periods. The effect of these methods is obvious, which can be seen on the change of air condition in Sichuan Province [11]. However, the basin's geographical challenges continue to affect pollution dispersion, making Sichuan still vulnerable to seasonal pollution spikes, so the government's laws still need to be extended to farther places.

(3) Moving excess cement production capacity overseas

Hebei government uses this strategy in order to reduce the pollution and PM2.5 concentration in the province. It also helps cement production in other neighbouring provinces or areas like Shanxi Province, Beijing or Tianjin. Beside these methods, encouraging innovative cement production design and subsidizing factories using NSP rotary kilns are also good method to reduce effect of cement production to the environment.

4.2. Changes of Environmental Impact in China

China has made significant progress in reducing greenhouse gases emissions from cement production in recent years. Great changes can be seen in the Fig. 9 [12]. Since 2011, although CO₂ emission is continuously growing, its growing rate is decelerating and even becomes negative in 2015. Moreover, the cement production becomes more evenly distributed while in 1993, the eastern region takes up most of cement production.

In addition, the concentration of PM2.5 in the air in provinces like Hebei or Sichuan has reduced significantly. Especially in Hebei Province, Fig. 10 shows that the concentration of PM2.5 in south part of Hebei decreases for over 50% from 2013 to 2020 [13]. These results are all part of China's progress in decarbonizing heavy industry and mitigating the effects of climate change.

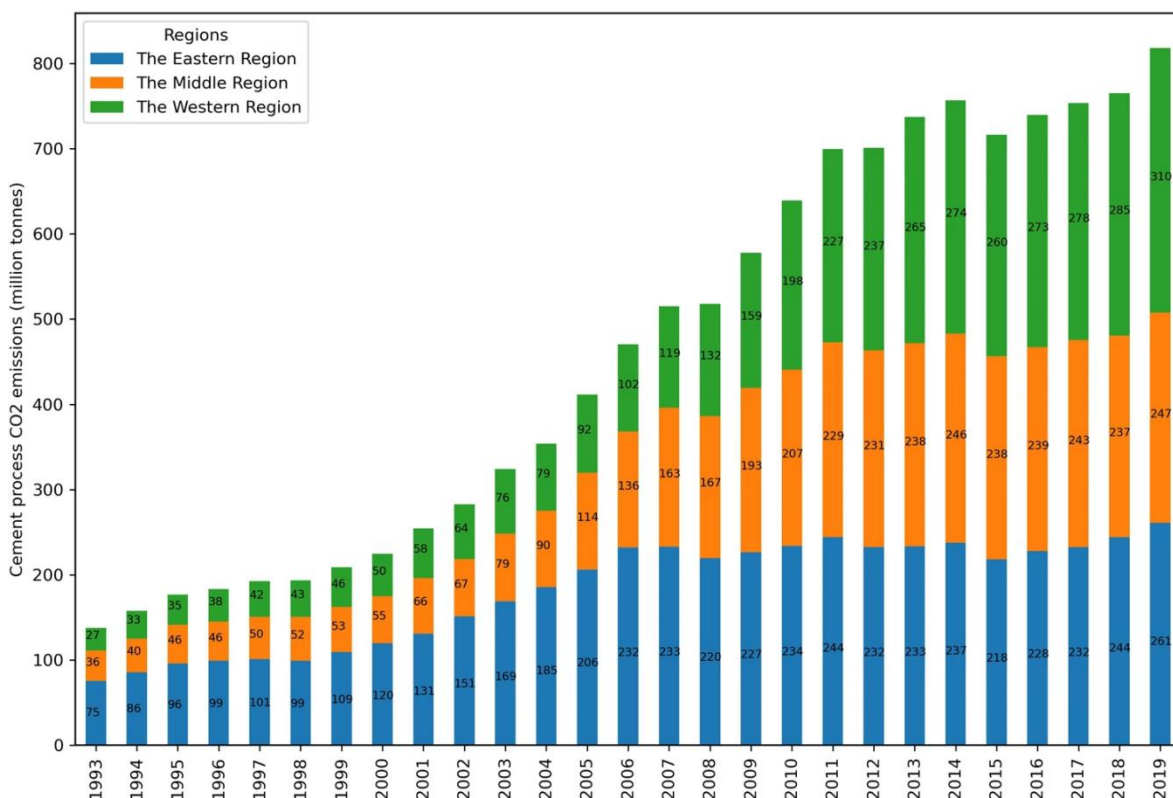


Figure 9. Changes of cement production pattern in China (Data from: [12])

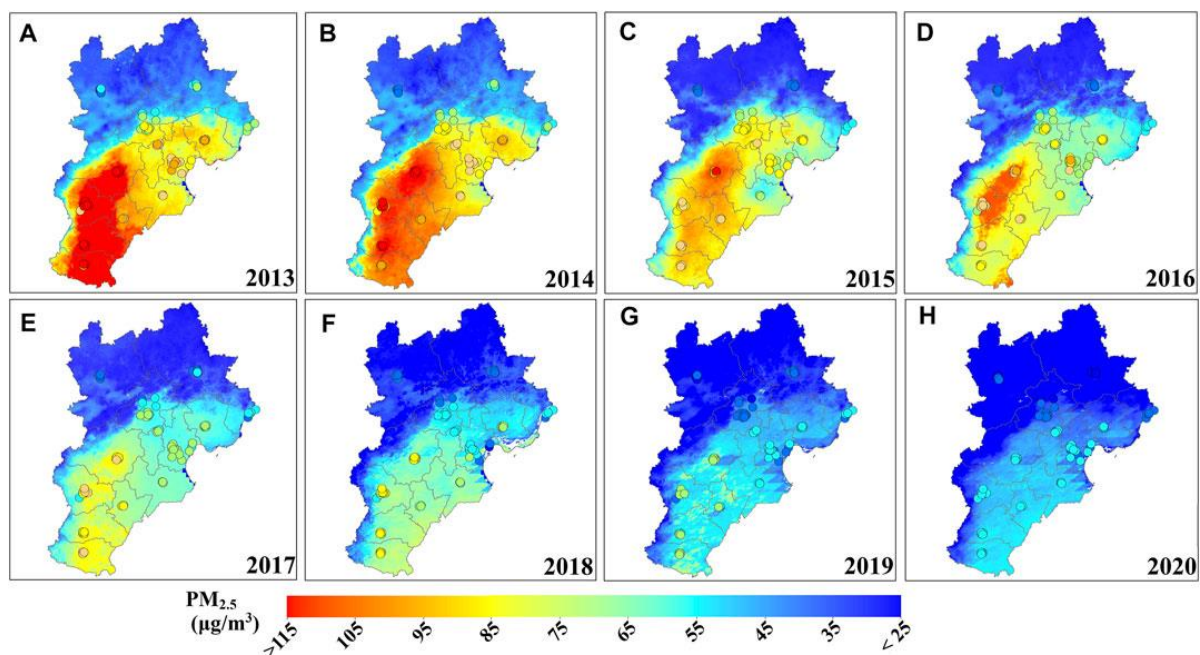


Figure 10. Changes of PM_{2.5} concentration in China [13]

5. Conclusion

This paper highlights the reason for significant shift in China's cement production methods, from traditional techniques like shaft and rotary kilns to the more energy-efficient and environmentally friendly NSP rotary kiln. The adoption of NSP rotary kilns has proven to substantially reduce carbon dioxide emissions, lower energy consumption, and mitigate the environmental impact of cement production, as evidenced by the much lower GWP values compared to older methods. Additionally, government policies such as off-peak gas emission planning and the relocation of excess production overseas have further contributed to curbing air pollution, particularly in high-polluting provinces like Hebei and Sichuan. China's progress in reducing PM_{2.5} concentrations and slowing the growth of CO₂ emissions in its cement industry is a positive step toward sustainable development. However, geographical challenges in certain regions like Sichuan and the sheer scale of production require continued innovation and policy enforcement. As China continues to decarbonize its heavy industries, the NSP rotary kiln production method serves as a model for other nations looking to balance industrial growth with environmental preservation.

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